NOTES ON KANSAS ROAD METAL.

By F. O. MARVIN, University of Kansas, Lawrence.

LAST year, Mr. N. M. McGillivray and Mr. E. H. Dunmire, seniors of the school of engineering of the University of Kansas, undertook an investigation of the various kinds of stone in the eastern part of the state to determine their relative value for the making of good roads. The work was carried on through the year, and an abstract of the results is hereby given.

The road laboratory is equipped with a Deval machine for testing resistance to impact and abrasion, a battery of Abbe flint-jar mills for fine grinding, a hydraulic press for making briquets from the fine dust, a Page cementation machine for breaking these briquets, and an apparatus for the freezing test. The collection of the stone was largely due to the aid of Professor Haworth, of the the Geological Survey.

The methods followed in making the tests were in the main those used by the road laboratory of the United States government. The Deval machine consists of a battery of four iron cylinders, 20 centimeters in diameter and 34 centimeters in length, set at 30 degrees to the axis of revolution. In each is placed five kilograms of dried stone broken to a standard size, to pass a six-centimeter ring and returned on a three-centimeter one. The cylinders are then closed with an air-tight cover and rotated at the rate of $33\frac{1}{3}$ revolutions per minute for a total of 10,000 revolutions. The per cent. of loss of weight caused by this action is taken as representing the value of the materials tested to resist impact and abrasion. The lower this per cent. the better the stone. In French practice it was found that the best stone for road purposes lost about 20 grams per kilogram, or two per cent. This figure 20 then was fixed as a standard of excellence and a formula $\frac{20 \times 20}{W}$ adopted as a coefficient to represent the comparative value of various stone, W being the weight in grams per kilogram of the loss in the Deval machine. The larger this coefficient the better the stone. This test has been standardized and adopted as being the best index of a stone value yet devised, although not alone conclusive.

The cementation test is designed to bring out a stone's cementing and binding power. For this, one kilogram of stone broken to small pieces is ground up to very fine dust in the porcelain jar

pebble mill. This dust, sifted through No. 7 bolting cloth, is mixed with water into a stiff dough, allowed to stand for twenty-four hours in tight jars, and then pressed by hydraulic power, with a maximum of 100 kilograms per square centimeter (1400 pounds per square inch), into cylinders one inch high and one inch in diameter (2.5 centimeters). These are oven-dried for twenty-four hours and then broken by blows in the Page machine. The blows are given by a one kilogram (2.2 pounds) rain falling a distance of one centimeter, the number of blows needed to fracture the briquet being taken to represent the cementing power of the material. Five briquets were tested for each sample. This test is of great value, but the methods of making it have not as yet been worked out with entire satisfaction. An impact test of a rain, falling in a small machine like a pile-driver on a small block cut from the actual stone, is often made, but this is not included in this series.

In the freezing and thawing tests, ten pieces of the stone to be tested were first dried thoroughly, then saturated, and frozen by being placed in the open air. When the temperature fell to 20 degrees F. or lower, the stone was considered sufficiently frozen. The stone was then thawed by steam, resaturated, and again frozen. After as many alternate freezings and thawings as would be obtained last winter, the loss of weight was determined. Also the stone that had been subjected to this process was put through the Deval machine and its loss by abrasion compared with that of unfrozen samples. The results have not been very satisfactory, because of the limited cold weather of last winter, the insufficient number of tests, and the experimental stage of the matter. On all samples tested there was a slight loss, due to freezing and thawing, varying from 0.28 per cent. to 1.25 per cent. The Deval test on stone subjected to the freezing test showed a loss sometimes larger and sometimes smaller than that from untreated stone. It is likely that the test may prove of some value, but there has been too little work done to warrant any conclusions.

Determinations of weight, specific gravity, porosity and absorption were also made.

Following is a table showing the results of the tests of the years 1905–'06:

TESTS OF KANSAS STONE AS TO VALUE FOR ROAD MAKING.

LIMESTONES.

Number	Location.	Geological name of stratum.	Loss; abrasion and impact	French coefficient.	Specific gravity	Porosity	Absorption	Loss by freezing test	Number of blows, cementation test
1	McCune	Fort Scott	3.67%	10.9%	2.69	0.89%	1.46%		
2	Coffeyville	Coffeyville	5.07	7.9	2.68	0.52	0.87		
3	Chanute	Iola	4.29	9.3	2.69	0.54	0.90		
4	Iola	"	9.38	4.3	2.66	3.36	5.13		
5	Osawatomie	"	4.25	9.4	2.70	0.02	0.04		
6	"	"	5.41	7.4	2.68	0.80	1.31		
7	Rosedale	"	5.36	7.4	2.85	2.68	4.43		
8	Argentine	Silicious	4.66	8.8	2.67	0.48	0.78		
9	"	Iola	5.69	7.0	2.71	0.32	0.32		
10	Garnett	Stanton	3.40	13.0	2.68	0.48	0.79		
11	Ottawa	"	5.62	7.1	2.64	1.42	2.26		
12	"	"	4.54	8.8	2.69	0.54	0.89		
13	"	"	5.94	6.7	2.67	2.22	3.49		
14	"	"	4.91	8.2	2.72	0.69	2.72		
15	Leavenworth	"	4.53	8.9	2.45	1.22	1.99		
16	"	Oread	7.00	6.1	2.59	2.48	3.77		
17	Lawrence	Kickapoo	4.55	8.8	2.68 2.67	1.40 1.08	2.26 1.75	0.44%	46
18	"	Oread	4.32	9.3	2.64	0.62	1.01	0.28	8
19	"	"	4.21	9.5	2.66	1.89	2.99	0.54	
20	"	"	5.91	6.8	2.72	3.16	4.95	0.42	
21	Williamsburg	"	5.82	6.9	2.59	2.26	3.44		
22	"	"	3.69	10.8	2.72	0.76	1.17		
23	Atchison	"	9.41	4.6	2.57	1.99	3.03	0.45	35
24	"	Lecompton	5.75	7.2	2.66	1.50	2.41		
25	Jefferson co	"	6.00	7.4	2.61	2.29	3.53	0.33	10
26	Oskaloosa	Deer Creek	4.45	9.0	2.67	1.08	1.75		
27	"	"	5.59	6.9	2.59	1.09	1.72		
28	Tevis	"	4.58	8.7	2.67	0.58	0.95	0.75	5
29	Valley Falls	Topeka	4.15	9.7	2.69	0.58	0.97		
30	"	"	6.12	6.7	2.68	1.09	1.77		
31	"	"	6.03	6.7	2.68	2.10	3.34		
32	Muscotah	Burlingame	3.58	11.4	2.69	1.60	2.58		
33	"	Wabaunsee	3.13	12.9	2.71	0.71	1.17		
34	Americus	Thin stratum	7.51	5.5	2.59	1 79	2.76	1.19	131
35	Americus	Americus	14.92	2.9	2.59	3.02	4.53		
36	Allen	Thin stratum	4.74	8.5	2.69	1.28	2.07	0.59	49
37	"	Americus	6.13	6.4	2.59	3.95	5.81		
38	Dunlap	Cottonwood Falls	8.71	4.6	2.72	2.05	3.32		64
39	Holton	Wabaunsee	5.15	7.9	2.59	2.29	3.50		
40	Soldier	"	6.25	6.6	2.58	2.63	3.97		
41	Seneca	"	6.03	7.3	2.63	1.30	2.09		
42	Frankfort	"	5.43	7.5	2.37				
43	"	"	4.50	10.5	2.48	1.53	2.28		
44	"	"	6.73	6.0	2.62	3.08	4.66		
45	"	"	9.27	4.3	2.54	3.76	5.47		
46	"	Cottonwood Falls	8.85	4.5	2.54	1.91	2.89		
47	Helmick		16.73	2.4	2.38	4.13	5.84	0.67	32
48	Dwight		30.08	1.3	2.31	2.05	2.83	0.84	12
49	Junction City	Fort Riley	14.92	2.9	2.50	5.62	7.74	0.73	19
50	Silverdale		20.55	2.0	2.58	5.73	8.05	0.28	
51	El Dorado		6.77	6.0	2.64	8.31	11.21	1.25	220
52	Marion	Marion	15.24	2.8	2.67	8.71	11.80		

CHERT.

53	Alta Vista	Cherty lines	10.51	3.8	2.62	3.14	4.75	0.92	38
54	Galena	Joplin flint	3.66	10.9	2.37	5.86	7.32		4

SANDSTONE AND DRIFT.

55	Redfield	Bandera sandstone	7.81	5.1	2.60	3.09	4.66		49
56	Lawrence	Drift boulders	2.22	22.2	2.64	0.03	0.05		
57	"	"	2.54	15.8	2.66	0.09	0.16		
58	"	"	1.51	26.6	2.40	0.09	0.15		

PAVING BRICK, FOR COMPARISON.

59	Coffeyville		5.40	7.4	2.44	1.50	2.21		

An examination of results shows that the farther west one goes the softer, lighter and more absorbent the rocks become, that the cementing value cannot be inferred from external appearance or from the results of other tests. Much more work is needed, as the present series is not extended sufficiently to warrant drawing definite conclusions.

If the results of the Deval test are taken as an index of relative value and expressed by means of the French coefficient, the best stone examined in this series ranges as follows:

No. 10....	Garnett, Anderson county	13.00
No. 30....	Muscotah, Atchison county	12.85
No. 33....	Muscotah, Atchison county	11.40
No. 1....	McCune, Crawford county	10.90
No. 21....	Williamsburg, Franklin county	10.80
No. 43....	Frankfort, Marshall county	10.45
No. 29....	Valley Falls, Jefferson county	9.65
No. 19....	Lawrence, Douglas county	9.50
No. 5....	Osawatomie, Miami county	9.40
No. 3....	Chanute, Neosho county	9 30
No. 18....	Lawrence, Douglas county	9 30

As to the rank of our limestones as compared with those of other sections, again using the Deval test as a basis, the following figures may be given: Thirty-five Maryland samples gave an average coefficient of 9.34; twelve Massachusetts samples, 10.4; thirty-three samples from all over the United States, 6.51; the fifty-two samples of this series from Kansas, 7.16. Leaving out the softer from Morris, Geary, and adjoining sections, the results would compare favorably with the above figures.

This investigation of Kansas stone for Kansas roads is being continued this year, and it is hoped to obtain more data and larger results.